VARIABLE RESISTANCE SHIFT RAIL DETENT ASSEMBLY AND SHIFT CONTROL METHOD EMPLOYING SAME

RELATED APPLICATIONS

This application is a continuation of U.S. Ser. No. 08/928,234 now abandoned filed Sep. 12, 1997, and assigned to EATON CORPORATION, the assignee of this application.

This application is related to U.S. Ser. No. 08/646,225 filed May 6, 1996, now U.S. Pat. No. 5,758,543, entitled SHIFT LEVER ASSEMBLY FOR MINIMIZING JUMPOUT, and Ser. No. 08/902,603 filed Aug. 7, 1997, now U.S. Pat. No. 5,904,635 entitled PARTIALLY AUTOMATED LEVER-SHIFTED MECHANICAL TRANSMISSION SYSTEM, both assigned to EATON CORPORATION, the assignee of this application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to shift rail detent mechanisms for providing a selectively variable resistance to axial or rotational movement of a shift rail for minimizing the occurrence of jumpout. In a particular preferred embodiment, the present invention relates to such a detent mechanism for a lever-shifted transmission system having means to determine a driver intent to initiate or continue a lever shift and, upon sensing such an intent, to cause the detent mechanism to provide a decreased resistance to shift rail movement.

2. Description of the Prior Art

Manually shifted vehicular transmissions of the simple and/or compound types and of the synchronized, blocked and/or non-synchronized types are well known in the prior art, as may be seen by reference to U.S. Pat. Nos. 5,000,060 and 5,390,561, the disclosures of which are incorporated herein by reference.

The prior art manually shifted transmissions, especially as utilized for heavy-duty vehicles such as straight trucks and conventional (i.e., not cab-over-engine) tractor/semi-trailers, utilized a manually manipulated shift lever extending upwardly from a shift tower subassembly mounted directly on the transmission housing and interacted with a multiple-rail or single shift shaft shifting mechanism of the types shown in U.S. Pat. Nos. 4,455,883; 4,550,627; 4,920,815 and 5,272,931, the disclosures of which are incorporated herein by reference.

While such transmissions are widely used and commercially successful, they are not totally satisfactory, as under certain severe road conditions, the transmissions may experience shift lever-induced jumpout (i.e., unintended disengagement of a gear ratio). This situation usually is associated with transmissions utilized in relatively heavy-duty vehicles (i e., such as MVMA Class 5 and larger vehicles), which tend to have relatively long shift levers having relatively large shift knobs, often including master valving for controlling range and/or splitter shifts, at the ends thereof.

As is known in the prior art, shift rail detent mechanisms are used to maintain the shift rails in a fixed position to resist jumpout, such as shift lever-induced jumpout. Examples of such detent mechanisms may be seen by reference to U.S. Pat. Nos. 4,550,627; 4,614,126; 4,920,815; 5,000,060 and 5,350,561, the disclosures of which are incorporated herein by reference. Shift lever detents are also useful to maintain a transmission in neutral when the engine is left running to keep the heater operational. Such mechanisms are not totally

satisfactory, as the magnitude of resistance to shift rail movement needed to provide a significant resistance to jumpout or to resist accidental shifting from neutral, often objectionably increased the operator effort associated with a lever shift.

Partially automated mechanical transmission systems providing automatic assistance, such as automatic engine fuel control, for manual lever-shifted transmissions are known in the prior art, as may be seen by reference to U.S. Pat. Nos. 4,593,580; 5,569,115; 5,571,059; 5,573,477 and 5,582,558, the disclosures of which are incorporated herein by reference, and to co-pending U.S. Ser. Nos. 08/649,829 now U.S. Pat. No. 5,682,790, 08/649,830 now U.S. Pat. No. 5,735,771, 08/649,831, now abandoned, and 08/666,164, all assigned to EATON CORPORATION, the assignee of this application. These systems utilize automatic engine fueling controls and/or range and/or splitter shift actuators, actuated by a driver indication of an intent to shift, allowing an old gear to be disengaged and a new or target gear to be engaged without requiring the driver to manipulate the clutch pedal (required only for vehicle launch and stop) or the throttle pedal.

SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, the drawbacks of the prior art are minimized or overcome by the provision of a selectively variable detent mechanism for a transmission system having a means for sensing a driver intent to initiate a lever shift, which provides a significant resistance to shift lever-induced jumpout without objectionably increasing the operator effort required to make an intended lever shift.

The foregoing is accomplished by providing a detent mechanism which may be controlled to a first condition for providing a greater resistance to shift rail movement or to a second condition for providing a lesser resistance to shift rail movement. Upon determining a driver intent to initiate a lever shift, and preferably until confirming engagement of a target gear ratio, the detent mechanism is caused to assume the second condition wherein detent resistance to shift rail movement (and, thus, to lever shifts) is minimized. When not at the initiation of or during a lever shift operation, the detent mechanism is caused to assume the first condition wherein a significant detent resistance to shift rail movement (and, thus, to shift lever-induced jumpout) is applied.

Alternatively, operation of the vehicle heater when the transmission is allowed to remain in neutral may cause the detent mechanism to assume the first condition.

Accordingly, it is an object of the present invention to provide a new and improved shift rail detent mechanism for mechanical transmission systems.

This and other objects and advantages of the present invention will become apparent from a reading of the following description of the preferred embodiment taken in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a symbolic representation of a vehicular drive line utilizing the improved shift rail detent assembly of the present invention.

FIG. 2 is a symbolic illustration of the parameters affecting shift lever-induced jumpout torque.

FIG. 3 is a symbolic illustration of the parameters affecting detent torque.

FIGS. 4A–4C are symbolic representations of a a heavy-duty, automatically assisted, manually shifted transmission system of the type advantageously utilizing the present invention.

FIGS. 5 and 6 are schematic illustrations of alternate variable resistance shift rail detent mechanisms.

FIG. 6A is a schematic illustration of the detent mechanism of FIG. 6 in a retracted position.

FIG. 7 illustrates a further alternate embodiment of the present invention.

FIG. 8 is a representation, in flow chart format, of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Certain terminology will be used in the following description of the preferred embodiment for convenience only and will not be limiting. The terms "upward," "downward," "rightward" and "leftward" will designate directions in the drawings to which reference is made. The terms "forward" and "rearward" will refer, respectively, to the front and rear ends of the drive train components as conventionally mounted in the vehicle, being, respectively, to the left and right sides of the various drive train components, as illustrated in FIG. 1. The terms "clockwise" and "counterclockwise" will refer to rotational directions as viewed from the left side of the vehicle, as shown in FIG. 1. Said terminology includes the words above specifically mentioned, derivatives thereof and words of similar import.

The preferred embodiment of the present invention is illustrated as utilized in a partially automated, lever-shifted mechanical transmission system of the type illustrated in aforementioned U.S. Pat. Nos. 4,593,580; 5,569,115 and 5,582,558, and in aforementioned co-pending U.S. Ser. No. 08/902,603, now U.S. Pat. No. 5,904,635, entitled PARTIALLY AUTOMATED LEVER-SHIFTED MECHANICAL TRANSMISSION SYSTEM. Although the present invention is particularly advantageously utilized in such systems, its application is not so limited.

A typical vehicular powertrain system **10** advantageously utilizing the present invention may be seen by reference to FIG. 1. Powertrain **10** is of the type commonly utilized in heavy-duty vehicles, such as the conventional tractors of tractor/semi-trailer vehicles, and includes an engine, typically a diesel engine **12**, a master friction clutch **14** contained within a clutch housing, a multiple-speed compound transmission **16**, and a drive axle assembly **18**. The transmission **16** includes an output shaft **20** drivingly coupled to a vehicle drive shaft **22** by a universal joint **24** for driving the drive axle assembly, as is well known in the prior art. The transmission **16** is housed within a transmission housing **26** to which is directly mounted the shift tower **28** of the shift lever assembly **30**.

FIG. 4A illustrates a shift pattern for assisted manual shifting of a combined range-and-splitter-type compound transmission manually shifted by a manually operated shift lever. Briefly, the shift lever **31** is movable in the side-to-side or X—X direction to select a particular ratio or ratios to be engaged and is movable in the fore and aft or Y—Y direction to selectively engage and disengage the various ratios. The shift pattern may include an automatic range shifting feature and automatically selected and/or implemented splitter shifting, as is known in the prior art. Manual transmissions utilizing shift mechanisms and shift patterns of this type are well known in the prior art and may be appreciated in greater detail by reference to aforementioned U.S. Pat. Nos. 5,000,060 and 5,390,561.

Typically, the shift lever assembly **30** will include a shift finger or the like (not shown) extending downwardly into a shifting mechanism **32**, such as multiple-rail shift bar housing assembly or a single shift shaft assembly, as is well known in the prior art and as is illustrated in aforementioned U.S. Pat. Nos. 4,455,883; 4,550,627; 4,920,815 and 5,272,931.

In the prior art transmissions of the general type illustrated in FIG. 1 but not incorporating the improved shift rail detent assembly of the present invention, it is known that annoying shift lever jumpout may occur if road conditions are severe. Briefly, shift lever jumpout is the unintended disengagement of the jaw clutches of a manually shifted transmission caused by shift lever oscillations in the Y—Y direction about the Y—Y pivot axis **34** of the shift lever assembly. It is the purpose of the shift rail detent assembly of the present invention to minimize the occurrences of such shift lever-induced jumpout while not objectionably increasing shift effort.

In a typical heavy-duty vehicle powertrain, the engine-clutch-transmission assemblage will tend to move, during severe road conditions, in a vertical manner (as illustrated by arrow **36**) and in a pivoting manner about a pivot point or axis **38** (usually located in the area of the vehicle clutch). As is indicated by arrow **40**, an upward movement of the assemblage almost always is associated with a counterclockwise rotation of the assemblage around pivot axis **38**, while, as indicated by arrow **42**, a downward movement of the assemblage almost always is accompanied by a clockwise rotation of the assemblage about the pivot axis **38**.

As understood, shift lever-induced jumpout is forced by the inertial effects of excessive road-induced vibration in the vehicle drive train. This road-induced shock causes the engine-clutch-transmission assemblage to pitch on its mounts, as shown in FIG. 1. This pitching occurs at the natural frequency of the engine-clutch-transmission-mount system, usually between about 7 and 10 HZ. This pitching induces relatively high vertical, fore-aft and rotational accelerations on the transmission and, in particular, the shift lever assembly. The shift lever assembly then develops an inertial jumpout torque T_j about its pivot **34** as determined by the sum of the inertial torques thereon, as will be described in greater detail below and as schematically illustrated in FIG. 2. It is noted that the typical rearward offset in transmission lever tends to increase the jumpout torque.

As will be described in greater detail below and as is schematically illustrated in FIG. 3, jumpout torque T_j is resisted by the shift rail or shift shaft detent force multiplied by its moment arm determined by the distance between the pivot **34** and the shift rail or shaft (i.e., detent torque T_0). Detent force may include the forces required to overcome a detent mechanism, torque lock in the engaged jaw clutches, and frictional forces in the shift mechanism. When the jumpout torque overcomes the detent torque, shift lever jumpout occurs. This tends to occur when the drive train has a very low torque, such as vehicle coast conditions, since the friction from so-called torque lock in the drive train during driving conditions tends to lock the engaged sliding clutch members in engagement and greatly overcomes any jumpout forces imposed thereon.

As the shift lever assembly **30** itself is a dynamic system, it has its own natural frequency. Unfortunately, this also usually occurs between 7 and 10 HZ. This frequency is determined by lever height, lever offset, tower height, and isolator stiffness. If the natural frequency of the engine-clutch-transmission assemblage matches that of the shift lever assembly, propensity for jumpout is greater because the engine-amplified inertial forces are amplified further by the lever resonance.

In FIG. 2,

$T_j = a_x My - a_y Mx + I$ where:

T_j =Jumpout torque

M=Mass of lever

I=Moment of inertia of lever

a_x=Fore/aft acceleration

a_y =Vertical acceleration

=Angular acceleration of lever

x=Distance between cg of lever and pivot

y=Vertical distance between cg of lever and pivot

cg=Center of gravity

while in FIG. 3,

$T_0 = F_x d$ where:

T_0=Detent torque

F_x=Detent force

D=Distance between pivot and rail

FIG. 2 illustrates a mathematical model for calculating the jumpout torque T_j induced in a shift rail by shift lever whip. It is noted that jumpout torque will be applied in both the counterclockwise and clockwise directions about the shift lever pivot axis **34** but will tend to cause jumpout only in one of those two directions, depending upon the currently engaged gear ratio.

One method of minimizing shift lever-induced jumpout is to increase the detent force F_x such that detent torque will almost always exceed jumpout torque. Unfortunately, such an increased detent force, if not relieved at the time of shifting, will result in objectionably high shift effort.

In a preferred embodiment of the present invention, the forward shifting of transmission **16**, comprising main section **16A** coupled to auxiliary section **16B**, is semi-automatically implemented/assisted by the vehicular semi-automatic transmission system **100**, illustrated in FIGS. 4A—4C. Main section **16A** includes an input shaft **50**, which is operatively coupled to the drive or crank shaft **110** of the vehicle engine **12** by master clutch **14**, and output shaft **20** of auxiliary section **16B** is operatively coupled, commonly by means of a drive shaft, to the drive wheels of the vehicle. The auxiliary section **16B** is a splitter type, preferably a combined range-and-splitter type, as illustrated in U.S. Pat. No. 5,390,561.

The change-gear ratios available from main transmission section **16** are manually selectable by manually positioning the shift lever **31** according to the shift pattern prescribed to engage the particular change gear ratio of main section **16A** desired. As will be described, manipulation of the master clutch (other than when bringing the vehicle to or when launching the vehicle from an at-rest condition) and manual synchronizing are not required. The system includes means to signal an intent to shift into a target ratio and will automatically take actions to minimize or relieve torque-lock conditions, allowing, if required, an easier shift into main section neutral from the engaged main section ratio and further allowing required splitter shifts to be automatically and rapidly completed upon a shift into neutral. Upon sensing a neutral condition, the system will cause the engine to rotate at a substantially synchronous speed for engaging a target gear ratio.

The system **100** includes sensors **106** for sensing engine rotational speed (ES), **108** for sensing input shaft rotational speed (IS), and **110** for sensing output shaft rotational speed (OS) and providing signals indicative thereof. As is known, with the clutch **14** engaged and the transmission engaged in a known gear ratio, ES=IS=OS*GR (see U.S. Pat. No. 4,361,060).

Engine **12** is electronically controlled, including an electronic controller **112** communicating over an electronic data

link (DL) operating under an industry standard protocol such as SAE J-1922, SAE J-1939, ISO 11898 or the like. Throttle position (operator demand) is a desirable parameter for selecting shifting points and in other control logic. A separate throttle posit on sensor **113** may be provided or throttle position (THL) may be sensed from the data link. Gross engine torque (T_{EG}) and base engine friction torque (T_{BEF}) also are available on the data link.

A manual clutch pedal **115** controls the master clutch, and a sensor **114** provides a signal (CL) indicative of clutch-engaged or disengaged condition. The condition of the clutch also may be determined by comparing engine speed to input shaft speed. A splitter actuator **116** is provided for operating the splitter section clutch (not shown) in accordance with command output signals. The shift lever **31** has a knob **118** which contains selector switch **120** by which a driver's intent to shift may be sensed. A preferred embodiment of selector switch **120** may be seen by reference to FIGS. 4A–4C. Switch **120** includes a body **120A** in which is pivotably mounted a rocker member **120B**. The rocker is spring-biased to the centered, non-displaced position illustrated. The operator may press surface **120C** or **120D** of the rocker member to cause the rocker switch to be pivoted in the direction of arrows **120E** or **120F**, respectively, to select an up- or downshift, respectively. The rocker may be moved in the direction of the arrows and then released to provide an "up" or "down" pulse or may be moved to and retained at the "up" or "down" positions to achieve different control results, as will be described in detail below. The rocker may be used to provide multiple pulses to request a skip shift (see U.S. Pat. No. 4,648,290). Alternatively, rocker **120B** may be replaced by a toggle, pressure-sensitive surfaces, separate "up" and "down" buttons, or the like.

A driver's control display unit **124** includes a graphic representation of the six-position shift pattern with individually lightable display elements **126, 128, 130, 132, 134** and **136** representing each of the selectable engagement positions. Preferably, each half of the shift pattern display elements (i.e., **128A** and **128B**) will be individually lightable, allowing the display to inform the driver of the lever and splitter position for the engaged and/or target ratio. In a preferred embodiment, the engaged ratio is steadily lit, while the target ratio is indicated by a flashing light.

The system includes a control unit **146**, preferably a microprocessor-based control unit of the type illustrated in U.S. Pat. Nos. 4,595,986; 4,361,065 and 5,335,566, the disclosures of which are incorporated herein by reference, for receiving input signals **148** and processing same according to predetermined logic rules to issue command output signals **150** to system actuators, such as the splitter section actuator **116**, the engine controller **112** and the display unit **124**. A separate system controller **146** may be utilized, or the engine ECU **112** communicating over an electronic data link may be utilized.

As shown in co-pending patent application U.S. Ser. No. 08/597,304, now U.S. Pat. No. 5,661,998, the splitter actuator **116** is, preferably, a three-position device, allowing a selectable and maintainable splitter section neutral. Alternatively, a "pseudo" splitter-neutral may be provided by deenergizing the splitter actuator when the splitter clutch **80** is in an intermediate, nonengaged position.

Forward dynamic splitter-only shifts, other than for the more fully automatic 9-10 and 10-9 splitter shifts, such as third-to-fourth and fourth-to-third shifts, are automatically implemented upon driver request by use of the selector switch **120**. By way of example, assuming a three-position splitter actuator, upon sensing that a splitter shift is required,

by receiving a single "up" signal when engaged in first, third, fifth of seventh, or receiving a single "down" signal when engaged in second, fourth, sixth or eighth, the ECU **146** will issue commands to the actuator **116** to bias the actuator toward neutral, and to engine controller **112** to minimize or break torque. This may be accomplished by causing the engine to dither about a zero flywheel torque value (see aforementioned U.S. Pat. No. 4,850,236). As soon as splitter neutral is sensed, the engine will be commanded to a substantially synchronous engine speed for the target gear ratio at current output shaft speed ($ES=IS=OS*GR_T \pm E_{RROR}$). The engagement is timed, in view of reaction times and shaft speeds and accelerations, to occur just off synchronous to prevent clutch butting. Automatic splitter shifting of this general type is illustrated in aforementioned U.S. Pat. Nos. 4,722,248 and 5,435,212.

The more fully automated 9-10 and 10-9 splitter shifts are implemented in the same manner but are initiated by the ECU, not the selector switch **120**, in accordance with predetermined shift schedules.

The engaged and neutral (not engaged) conditions of transmission **10** may be sensed by comparing the input shaft/output shaft rotational speeds to known gear ratios ($IS/OS=GR_{i=1\ to\ 10} \pm Y$?) for a period of time. Position sensors may be utilized in lieu of or in addition to input shaft and output shaft speed logic.

When synchronizing to engage a target ratio, the engine is directed to achieve and remain at a speed about 30 to 100 RPM (preferably about 60 RPM) above or below (preferably below) true synchronous speed ($ES_{SYNCHRO}=(OS \times GR_T)-45$ RPM) to achieve a good quality jaw clutch engagement without butting. To verify engagement of a target ratio, the system looks for input shaft speed equaling the product of output shaft speed and the numerical value of the target ratio, plus or minus about 10 to 30 RPM ($IS=(OS*GR_T) \pm 20$ RPM) for a period of time, about 100 to 400 milliseconds.

The foregoing logic allows transmission engaged and neutral conditions to be determined on the basis of input and output shaft speeds without false engagement sensing caused by engine synchronizing for engagement of a target ratio (see co-pending U.S. Ser. No. 08/790,210, now U.S. Pat. No. 5,974,354).

When in an even numbered ratio (i.e., when in the high splitter ratio) and a single upshift is required, a lever upshift (with splitter downshift) is appropriate and the system, if requested by the driver, will automatically assist in implementing same. Similarly, when in an odd numbered ratio (i.e., when in the low splitter ratio) and a single downshift is requested, a lever downshift (with splitter upshift) is appropriate and the system, if requested by the driver, will automatically assist in implementing same. It is noted that in system **100**, splitter-only shifts may be automatically implemented, while lever shifts, with accompanying splitter shifts, require driver initiation and main section jaw clutch manipulation.

When a combined lever-and-splitter shift is requested, a single pulse of the selector in the appropriate direction (as opposed to maintaining the rocker **120B** in the appropriate displaced position) is taken as simply a request for an appropriate splitter shift with no automatic assistance, and the splitter will be preselected to shift to the appropriate splitter position and will do so when the operator manually shifts to neutral or otherwise breaks torque. The driver is then required to engage the appropriate main section ratio without intervention by the controller **148**. This is substantially identical to the operation of a fully manual splitter-type transmission.

If the driver wishes automatic assistance for a combined lever-and-splitter shift, the rocker member **120B** of the selector is moved to and retained (for at least 50 milliseconds to 1 second) in the appropriate position to request an assisted up- or downshift. The controller **148**, upon receiving such a request, will automatically cause (for a period of about 2–5 seconds) the engine to be fueled to dither about a zero flywheel torque, thereby reducing or eliminating torque lock conditions and allowing the operator to easily manually shift to main section neutral (see U.S. Pat. Nos. 4,850,236 and 5,573,477). The display **124** will steadily light the old gear ratio and flash or otherwise indicate the selected ratio. The ECU **148** will sense for neutral conditions by comparing the ratio of input shaft speed (IS) to output shaft speed OS) to known gear ratios. Alternatively or in combination, position sensors may be utilized. The logic will determine the identity of the target gear ratio GR_T as a direct or indirect function of current gear ratio GR_C and the direction of the requested shift.

When main section neutral is sensed, the display element corresponding to the disengaged gear ratio will not be lighted, the splitter will automatically be caused to shift to the appropriate splitter ratio and the engine will automatically be caused (for a period of about 2–5 seconds) to rotate at a substantially synchronous speed ($ES=OS*GR_T$) for engaging the target gear ratio (GR_T), allowing the operator to easily manually utilize the shift lever **31** to engage the indicated main section ratio. Preferably, the engine will automatically be caused to rotate at an offset from or to dither about true synchronous speed (see U.S. Pat. Nos. 5,508,916 and 5,582,558). Upon sensing engagement of the target ratio, the display indicator element corresponding to the newly engaged ratio will be steadily lit and engine fuel control will be returned to the operator. The assisted combined lever and splitter shift is accomplished without requiring the operator to manipulate the clutch pedal **115** or the throttle pedal **113**.

When in or after shifted to the "A" position **136** (i.e., 9/10), the ECU **146** will command the fuel controller **112** and splitter operator **116** to automatically select and implement appropriate 9-10 and 10-9 shifts. Automatic operation within an upper group of ratios is disclosed in aforementioned U.S. Pat. Nos. 4,722,248; 4,850,236 and 5,498,195. Systems incorporating this feature are sold by Eaton Corporation under the "Super 10 Top-2" trademark and by Dana Corporation under the "Automate-2" trademark.

To shift out of the "A" position, the operator may simply use the clutch pedal **115**, throttle pedal **113** and shift lever **57** to perform a fully manual shift to another ratio. If an assisted lever shift from "A" to eighth (or a lower ratio) is required, the selector rocker **120B** may be retained in the "down" position, which will cause the ECU **146** to command the fuel controller **112** and/or splitter actuator **116** to assist the lever or combined lever-and-splitter shift from the engaged "A" ratio (ninth or tenth) to a selected target ratio. Pulses of the selector (and "up" continuing displacements), when in the "A" position, are ignored by the ECU.

In transmission systems such as system **100**, and in more automated systems, the system is provided with a signal indicating, or with a means for determining, that a shift in the main transmission section **16A** is to be initiated.

According to the present invention, a detent mechanism is provided which will provide a variable resistance to shift rail movement from an engaged position. When the system senses a desire to remain in an engaged ratio, the detent provides a detent force which will provide an exceedingly nigh resistance to shift rail movement which will resist shift